

Understanding Hydrogen Passivation Mechanism in poly-Si Passivating Contacts: Insights from Effusion Studies

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Introduction

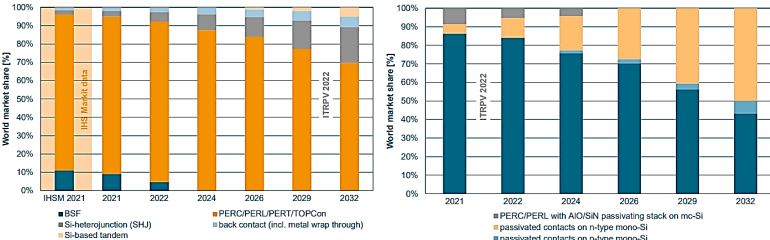


Fig. 1 World market share of different cell technology

Fig. 2 World market share of PERC/PERL/PERT/TOPCON Technology

Source: ITRPV Roadmap, 13th Edition, Mar 2022

1. Silicon PV is the dominant PV technology, and captures >95% world market share, supporting ~100 GW/year.
2. Diffused and passivated pn junctions along with other rear side passivation technologies are the mainstream technologies and will continue to remain so in the coming decades.
3. Passivated contacts, using tunnel oxide passivation stacks at the rear side, will gain market share from about 10% in 2022 up to 58% within the next 10 years.
4. Most mature approaches use passivating layers of hydrogenated Al₂O₃ and SiN_x.

Motivation

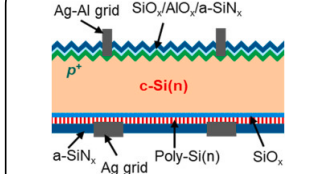


Fig. 3 Schematic structure of a TOPCON solar cell (Image ref: Kalle et al., Sol. Energy Mater. Sol. Cells, 227, p.111100)

- Screen printing and subsequent firing is the most dominant metallization technology in the industry and will remain so, for years to come.
- During firing, a rapid ramp-up of temperature up to temperature ~800°C is required within a few seconds, which releases hydrogen from the dielectric layers
- We want to retain hydrogen even at high temperatures to maintain passivation during metallization in TOPCON solar cells

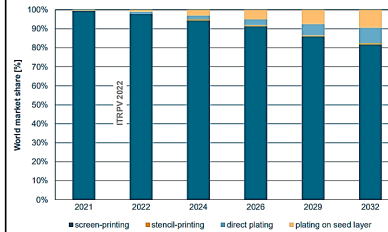


Fig. 4 Expected Market Share of front side metallization technologies

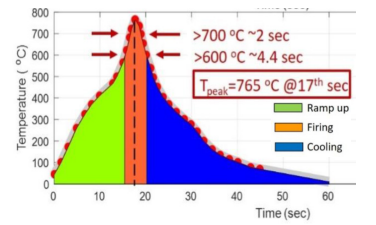


Fig. 5 Typical temperature profile in firing processes (Image ref: Mitra et al., Surfaces and Interfaces 25 (2021) 101260)

Objectives

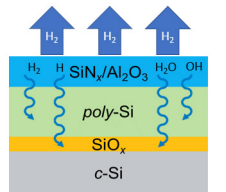


Fig. 6. Movement of hydrogen within the structure Ref: Hartenstein, et al. (2022) MRS Spring Meeting

- Influence of different deposition techniques of SiN_x namely, PECVD or LPCVD on H-effusion due to firing
- Mechanism of hydrogenation in polySi using forming gas annealing (FGA), AlO_x:H+FGA and SiN_x+FGA using
- H-effusion mass spectroscopy
- FTIR spectroscopy
- Establish the ion-exchange with moisture in atmosphere through dielectric layers into polySi

Influence of different deposition techniques: LPCVD & PECVD

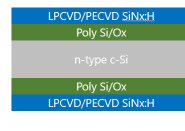


Fig. 7 Sample structure to study the role of SiN_x:H in poly-Si passivation

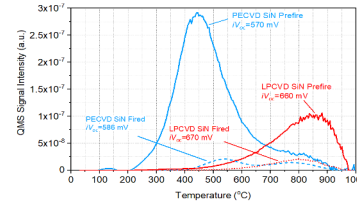


Fig. 8 Temperature dependent effusion for samples shown in Fig. 7

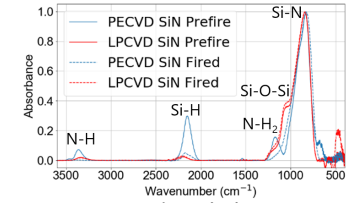


Fig. 9 FTIR for samples shown in Fig. 7

- IV_{oc} increased in both the cases after FGA treatment and firing
- Amount of hydrogen effused in PECVD SiN_x > LPCVD SiN_x.
- But LPCVD SiN_x could retain the hydrogen to a much higher temperature of ~850°C compared to ~450°C

Influence of different dielectric layers on H-effusion

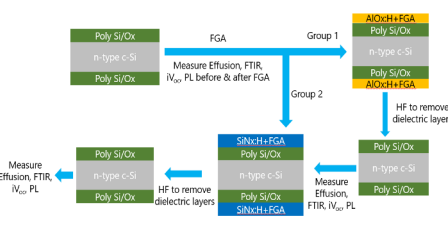


Fig. 10 Sample preparation to study H-transfer to poly-Si

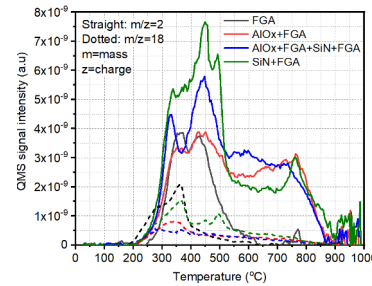


Fig. 11 Temperature dependent effusion for samples shown in Fig. 10

Cathodoluminescence

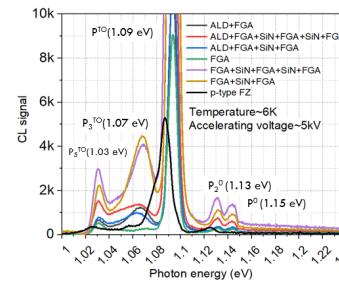


Fig. 12 Cathodoluminescence of samples shown in Fig. 10 at 6K with an accelerating voltage of 5kV

▪ Hydrogen has reached c-Si and passivated the dangling bonds

▪ Both single SiN treatment or double SiN treatment both have passivated well compared to ALD+SiN treatment, single ALD treatment or FGA treatment.

Influence of ambient moisture

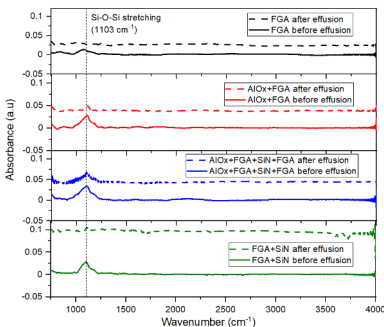


Fig. 13 FTIR for samples shown in Fig. 10

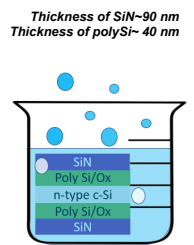


Fig. 14 Samples in boiling D₂O

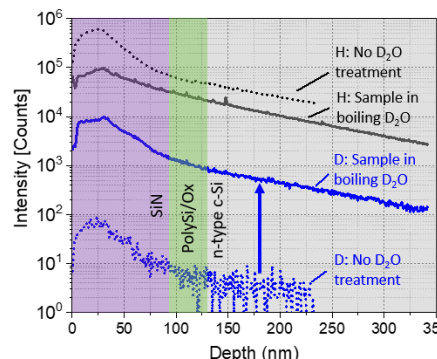


Fig. 15 SIMS profile for the sample in boiling D₂O

Conclusions

- LPCVD SiN_x provides less hydrogen for passivation compared to PECVD SiN_x but can retain the hydrogen up to higher temperatures which is beneficial for firing.
- Although SiN_x provides large amount of hydrogen, this doesn't necessarily translate to good passivation. AlO_x:H contributes to retaining H at higher temperatures.
- Water molecules are also detected during H-effusion and may play a role in passivation of the oxide/wafer interface.

Acknowledgement

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